ENERGY STAR® Electric Vehicle Supply Equipment (EVSE) Version 1.1 Specification and Test Method Discussion Guide

May 2018

I. Overview

The U.S. Environmental Protection Agency (EPA) is sharing this ENERGY STAR Version 1.1 EVSE Discussion Guide to invite stakeholder input on key elements in advance of a Version 1.1 Draft Specification and Test Method. The goal of the Version 1.1 EVSE Specification is to include DC Output EVSE into the scope of the specification.

EPA feels the following topics are important to discuss with stakeholders prior to a Version 1.1 Draft release and they are the subject of this document:

- Developing an appropriate test procedure for DC charging, including lab requirements and test setup, relevant modes, and measurements;
- Definitions;
- Scope; and
- EVSE modes subject to ENERGY STAR requirements.

As always, stakeholder engagement is a vital ingredient in the success of the ENERGY STAR program, and EPA looks forward to working with all parties to develop the ENERGY STAR Version 1.1 EVSE specification and test method. **EPA will host a webinar on Monday, June 4, 2018 from 12:00 PM – 2:30 PM Eastern Time** to engage with stakeholders on the content included in this discussion guide. Please register here to attend. Also, EPA encourages stakeholders to provide written input and relevant data on this topic to evse@energystar.gov by **Monday, June 25, 2018.**

II. Applicability of Existing Test Method to DC EVSE

Where possible, EPA is considering applying portions of the current ENERGY STAR test method for AC Output EVSE to DC EVSE. As such, EPA expects to divide the current test method requirements into two parts:

1. Requirements that are generally applicable to both Level 1 and Level 2 AC EVSE as well as DC EVSE; and
2. Requirements that are only applicable to AC EVSE.

To these, EPA expects to add a third part:

3. Requirements that are only applicable to DC EVSE.

The sections below present the structure of this revised test method, along with EPA questions on specific aspects of it. Subsequently, in Section VI, EPA lays out proposals related to a DC charger specification (power and efficiency criteria). EPA welcomes feedback on all aspects of these proposals.

III. Test Setup

EPA is considering an expansion of the test set up instructions in the Version 1.0 EVSE test method to include separate DC EVSE requirements.

1) General Requirements for Both AC and DC EVSE

A) Current Input Power Measurements from ENERGY STAR Final Test Method, Rev. Apr-2017

B) Current Power Meter and Illuminance Meter Accuracy Requirements

2) AC EVSE Requirements

A) Current test setup

B) Current AC input power table

C) Current ambient conditions
D) Current Test Load

3) DC EVSE Requirements

A) There is no need for the differential measurement method, used in the AC Output test procedure as the losses will be much larger and easier to measure for DC Output. As a result, EPA proposes the test setup shown in Figure 1 for DC EVSE.

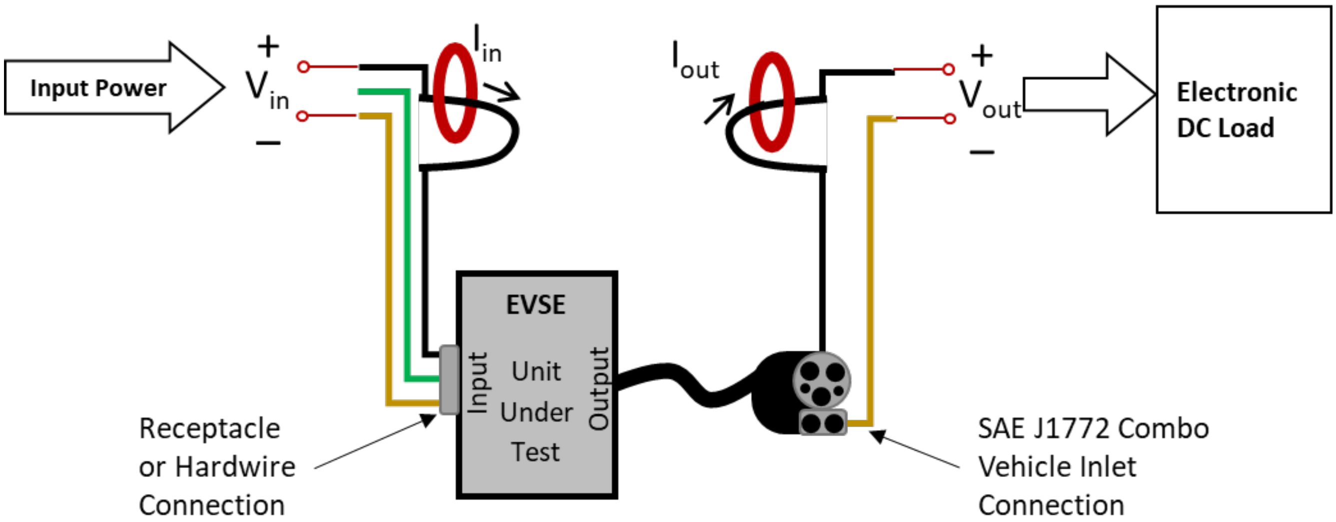

Figure 1: Schematic of Test Method Connection <u>for DC EVSE</u>

B) Higher-voltage AC input power required for DC EVSE:
EPA proposes a standard list of input voltages in Table 1; EVSEs would be tested at the highest compatible voltage from the below list. This list is based on the input supply requirements in the ENERGY STAR Uninterruptible Power Supply test method.

i) Voltages include typical ones used in North America and Europe, with voltages lower than 400 V removed due to a lack of products at those voltages (and an expectation that future products will have higher output power and correspondingly higher input voltage).
ii) A set list of test voltages allows for comparisons between EVSEs that may have slightly different input voltage ranges.
iii) Testing would be conducted without an external transformer.
iv) EVSEs that support both 3-phase and single-phase input power shall be tested using 3-phase power (indicated with a Δ symbol for delta-connected three-phase, and Y for wye-connected three-phase).

EPA welcomes feedback on this approach.

Table 1: Proposed Input Supply Requirements <u>for DC EVSE</u>

Voltage and Precedence	Frequency
1. 600Δ V ac	60 Hz
2. 600Y/346 V ac	60 Hz
3. 480Δ V ac	60 Hz

Voltage and Precedence	Frequency
4. 480Y/277 V ac	60 Hz
5. 415∆ V ac	60 Hz
6. 415Y/240 V ac	60 Hz
7. 400∆ V ac	50 Hz
8. 400Y/230 V ac	50 Hz

C) DC Test Load:

A DC Test Load shall be used for testing DC Output EVSE. The DC load shall be combined with a Vehicle Emulator Module (VEM) that can communicate per SAE J1772 Appendix F and G.

D) Representative testing temperatures for a hot and cold climate to exercise on-board cooling and heating:

EPA has heard that charging efficiency can vary substantially depending on the ambient temperature, both due to different cooling technologies (air cooling, liquid cooling) as well as strategies (cooling system engaging at different temperatures or times). As a result, EPA believes that it will be important to select a few representative temperatures to appropriately simulate what a charging event would may look like in various climates across the country.

EPA is proposing to conduct both No Vehicle and On Mode testing at three temperatures that are based on EPA's Five Cycle Fuel Economy testing[1]. For the cold and hot temperature conditions, EPA used the values from the Fuel Economy testing exactly; for the temperate condition, EPA chose a temperature at the lower end of the Fuel Economy testing temperature range (which is 68–86° F). In all cases, EPA proposes an allowable variation of ± 5° F.

Table 2: Proposed Testing at Representative Temperatures for DC EVSE

Type of Climate	Representative Temperature
Cold	20° F or –7° C (± 5° F, ± 2.5° C)
Temperate	68° F or 20° C (± 5° F, ± 2.5° C)
Hot	95° F or 35 ° C (± 5° F, ± 2.5° C)

Discussion Questions

1) It is important to note that the input power measurement would be taken at the input to the EVSE, not at the utility panel. For a DC EVSE that has a separate cabinet containing the AC/DC converter, and a dispenser that connects to the vehicle, the input power measurement would be taken at both the cabinet and the dispenser. Should EPA accommodate a lower voltage (120 V) connection to the dispenser (i.e., there may be two input voltages)?

2) For these EVSEs with a separate cabinet and dispenser, how should EPA factor in the losses in the DC cable connecting the two enclosures?

[1] EPA, "Detailed Information", https://www.fueleconomy.gov/feg/fe_test_schedules.shtml.

3) EPA is requesting stakeholder feedback on the proposal to test at the representative temperatures listed in Table 2. Are these temperatures representative of climates across the United States? EPA would also welcome data on the variations in efficiency that result from charging in different climates.

4) Do laboratories have atmospheric-controlled testing chambers to do the above proposed testing; if not, is acquiring this capability doable? Are there alternative methods for conducting temperature testing that could minimize potential testing burden?

5) EPA requests feedback around the ±5° F variation around the temperature conditions.

IV. Test Conduct

EPA is considering applying the existing test conduct section to both AC and DC EVSE, as follows:

1) General Requirements for Both AC and DC EVSE

A) As-shipped configuration for testing

B) Network connection capabilities

C) Luminance testing for products with a display

D) Measurement accuracy

Discussion Questions

6) EPA welcomes feedback on whether DC-output EVSE are commonly custom builds, and if so, suggestions of how to select representative configurations for test to minimize testing burden.

V. Test Procedures

1) General Requirements for Both AC and DC EVSE

A) UUT (Unit Under Test) Preparation

   i) This test procedure would remain the same for DC output EVSE

B) No Vehicle Mode (State A) Testing

C) Full Network Connectivity Testing

2) AC EVSE Requirements

A) Partial On Mode (State B) and Idle Mode (State C) Testing

   i) EPA understands that there may not be a relevant Partial On or Idle Mode for DC Output EVSE because the EVSE is either in a mode where there is no vehicle present (No Vehicle Mode) or when it is actively charging a vehicle (Operation Mode)

B) Current Operation Mode (State C) Testing

3) DC EVSE Requirements

EPA sees that it is important to develop separate DC EVSE test procedure requirements due to the uniquely different nature of DC Fast Charge. It follows that the Version 1.1 should also include different loading conditions (shown in Table 3).

The goal of testing at these various conditions will be to demonstrate the efficiency at the maximum power output and then as the charge begins to ramp down when the vehicle is no longer accepting maximum current. EPA expects that testing at each load condition will be brief (~5 minutes) and believes that having 5 loading conditions will not be overly burdensome as a result.

The output powers are based on levels that EPA has seen in the market or understands are under development, while the voltages are based on popular EV battery pack voltages at full charge. For the maximum power, EPA is proposing a voltage that is calculated from the maximum power by dividing by 0.5 A and adding 300 V, to provide a voltage proportional to power, and results in 1300 V at 500 kW and 400 V at 50 kW. EPA has proposed ± 2% tolerance as in the current AC EVSE test procedure.

A) Separate DC Operation Mode (State C) Testing
   1) EPA will reference new information from SAE J1772 Appendix F regarding signaling for DC EVSE to specify the power for test. Testers will have to use specialized test equipment that will be able to communicate with the EVSE and read its maximum current and perform required handshaking in order to test at the conditions listed in Table 3.

   2) EPA is proposing the following testing conditions for On Mode. EPA welcomes feedback on the typical battery characteristics, including battery voltage at full charge, of EVs that will charge at the following conditions:

Table 3: Proposed On Mode Test Conditions for DC EVSE

	Test Conditions	Example for 500 kW capable UUT	Example for 350 kW capable UUT	Example for 150 kW capable UUT
Loading Condition 1	Max Available Power Output ± 2% and Voltage = Pout / 0.4 A + 300 V ± 2%.	500 kW	350 kW	150 kW
Loading Condition 2	350 kW ± 7 kW and 900 V ± 18 V	350 kW	Tested above	Do not test
Loading Condition 3	150 kW ± 3 kW and 400 V ± 8 V	150 kW	150 kW	Tested above
Loading Condition 4	50 kW ± 1 kW and 350 V ± 7 V	50 kW	50 kW	50 kW
Loading Condition 5	30 kW ± 0.6 kW and 350 V ± 7 V	30 kW	30 kW	30 kW

EPA reviewed typical battery capacities of some of the most popular vehicles that can accept DC charging to inform the above test conditions. The results of this research are shown in Table 4.

Table 4: Typical Battery Characteristics of Popular EVs

Popular EV	Energy Capacity	Voltage	Battery Range
Vehicle 1	60 kWh	350 V	230 miles
Vehicle 2	40 kWh	384 V	151 miles
Vehicle 3	33 kWh	353 V	114 miles
Vehicle 4	33.5 kWh	325 V	115 miles
Vehicle 5	75 kWh	400 V	259 miles

3) Due to the high power levels of DC EVSE, EPA will explicitly allow back-feeding the output into the input, to minimize source requirements. The following language is currently used in the ENERGY STAR Uninterruptible Power Supplies (UPS) test method:

Backfeeding the source may be used in place of a test load during testing of UPS systems larger than 100 kW output, provided that an output power factor greater than 0.99 is maintained at all times.

Discussion Questions

7) Are there other relevant modes for DC Output EVSE, besides No Vehicle and Operation Mode, which should be accounted for in this test procedure?

8) How should EPA best account for the power required to provide liquid cooling to the cables?

9) EPA has learned from stakeholders that DC EVSE manufacturers are moving away from 25 kW or 50 kW stations and toward 150 kW and 350 kW stations. However, there will continue to be legacy vehicles that charge at a maximum of 50 kW, dropping below 30 kW as the battery approaches a fully charged state. As a result, EPA has included these lower charging states in Table 3 as testing conditions.

   a. EPA welcomes feedback on the appropriateness of the testing conditions in Table 3. Should EPA consider different testing conditions to determine the efficiency of On Mode charging?

   b. In addition, EPA welcomes feedback on an appropriate testing voltage for the various testing conditions.

10) EPA has learned that the cooling system of EVSEs will typically turn on after the EVSE reaches a particular temperature (either due to the ambient temperature or internal heating from operating at high power). EPA is interested in learning about cooling strategies to minimize cooling and increase the efficiency of the overall charge. EPA welcomes feedback on the typical operating characteristics of cooling systems and how to structure and sequence tests so they are representative.

11) EPA has learned that some EVSE may contain battery banks for the purpose of reducing peak demand (kW). As a result, EPA would like stakeholder feedback on the following testing proposals to account for energy loss from the battery itself:

   a. Should EPA consider conducting a 24-hour test?

   b. Should EPA require that the battery is disabled for one test and enabled for a second test?

12) For DC EVSE, with a separate cabinet (containing the AC/DC converter) and dispenser (connects to the vehicle), should EPA consider an alternative testing approach that involves splitting up the cabinet and dispenser into separate tests?

   a. The No Vehicle Mode testing may be most applicable for the dispenser, perhaps in light and dark conditions, with a variety of temperatures.

   b. The Active Mode testing may be more applicable for the cabinet at a variety of output powers (without lighting or temperature variations).

VI. Specification Considerations

In order to accommodate DC Output EVSE in the Version 1.1 specification, EPA is considering including the following:

1) Definitions

a. Electric Vehicle Supply Equipment (EVSE): The conductors, including the ungrounded, grounded, and equipment grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the electric vehicle. Charging cords with NEMA 5-15P and NEMA 5-20P attachment plugs are considered EVSEs. Excludes conductors, connectors, and fittings that are part of the vehicle.
   i. Level 1: A galvanically-connected EVSE with a single-phase input voltage nominally 120 volts ac and maximum output current less than or equal to 16 amperes ac.
   ii. Level 2: A galvanically-connected EVSE with a single-phase input voltage range from 208 to 240 volts ac and maximum output current less than or equal to 80 amperes ac.
   iii. DC: A galvanically-connected EVSE that includes an off-board charger and provides DC current greater than or equal to 80 amperes DC.
   iv. Wireless / Inductive: A non-galvanically-connected EVSE.

Discussion Questions

13) Does the above definition for DC EVSE appropriately account for DC Output products?

14) The SAE J1772 standard contains definitions for Level 1 and Level 2 DC EVSE. Should EPA align with these definitions?

2) Scope
   a. Included Products – The included products from Version 1.0 will remain – Level 1, Level 2, and Dual Input Level 1 and Level 2 EVSE – and DC EVSE will now be included in scope.

Discussion Questions

15) Would purchasers benefit from additional information on more efficient distribution transformers, as presented in the *ENERGY STAR Distribution Transformers Buying Guide*[2] document because a transformer may need to be purchased for specific sites where DC EVSE will be installed?

16) Wireless charging: Should EPA consider including wireless charging units in Version 1.1? What are the benefits and barriers for this technology that would make it appropriate or inappropriate for consideration at this time?

3) Performance Criteria
EPA gathered available research regarding power use in Operation Mode, No Vehicle Mode, and to operate various features commonly included with DC EVSE, which is presented below. EPA is interested in gathering this information to inform the development of efficiency criteria for DC EVSE but is not proposing any criteria at this time. Rather EPA would appreciate any stakeholder feedback and data on power consumption; including:
   a. Operation Mode: Claimed efficiency ranges for DC EVSE on the market appear to be between 92% and 97% when the EVSE is actively charging at full output. On Mode testing on one DC EVSE conducted by Idaho National Laboratory (INL) found efficiency at 30–50 kW ranging 91–93%, and lower efficiency at lower power levels[3]. For another EVSE, the efficiency was 86–89%, including transformer losses[4].

[2] https://www.energystar.gov/products/avoiding_distribution_transformer_energy_waste
[3] Idaho National Laboratory, "DC Fast Charger Fact Sheet: ABB Terra 53 CJ charging a 2015 Nissan Leaf", June 3, 2016, https://avt.inl.gov/sites/default/files/pdf/evse/ABBDCFCFactSheetJune2016.pdf.
[4] U.S. Department of Energy, "Production EVSE Fact Sheet: DC Fast Charger: Hasetec", https://avt.inl.gov/sites/default/files/pdf/evse/DCFCHasetec.pdf

The International Energy Agency (IEA) and 4E published the following efficiency testing results based on manufacturer interviews[5]:

Company interviews								
			Active	Standby power				
Name	Type	Overall charge efficiency	Loading cable cooling	Idle	Signalling	Standby heating/cooling	Year
		[%]	[W]	[W]	[W]	[W]	
Company A	50kW DC Fast charge	92,00%	1000	80	unknown	500	2017
Company B	60kW DC Fast charge	95,00%	unknown	40	50	80-100	2017

b. No Vehicle Mode: Measurements by INL ranged from 99 W before charging, to 150 W immediately after charging (due to cooling fan), and 110 W after charging[3].
c. EPA has learned from stakeholders that there is no Off Mode state for DC EVSE – it is either in a No Vehicle Mode or in Operation Mode.
d. Secondary and Tertiary Functions: EPA understands that the following functions operate during these modes and is providing any readily-available data on power consumption of these functions:
   i. Ambient lighting
      1. The IEA-4E report noted that a manufacturer had stated that 50 W is needed for LED signal lighting[5]. EPA believes that this would be the power required to provide light for multiple DC EVSE at one location, rather than for just one EVSE.
   ii. Cooling/heating (depending on the temperature)
      1. Through manufacturer interviews, the IEA-4E report concluded that certain functions, like heating and cooling, may significantly affect the energy performance and need to be considered. Manufacturers indicated a vast range of potential power requirements for heating and cooling, from 80 W for heating and 100 W for cooling, to a combined 500 W requirement[5].
   iii. Liquid cooling of the cables
      1. A stakeholder has noted that liquid cooling can draw about 1 kW
   iv. High-resolution display
   v. Network connection – Wi-Fi, Cellular, other
e. EPA is interested in the power factor associated with DC EVSE in each mode.

Discussion Questions

17) Are there other modes that should be considered besides No Vehicle and Operation Mode? Do stakeholders have additional information on power consumption to share?

18) What other features or functions are missing from the above list that should be taken into consideration for setting criteria for maximum power consumption?

    a. EPA would welcome data on the power consumption of any of these features.

4) Modular products – EPA is considering the testing of minimum and maximum power configurations to represent in-between configurations, similar to what is required in the ENERGY STAR Uninterruptible Power Supplies (UPS) Specification:

   For qualification of a Modular UPS Product Family where models vary by number of installed modules, the manufacturer shall select the maximum and minimum configurations to serve as Representative

[5] IEA-4E EDNA Workshop on Efficient Electric Vehicle Supply Equipment – EVSE, “EVSE Scoping Study for 4E”, September 28, 2017, https://nachhaltigwirtschaften.at/en/iea/events/2017/20170928-workshop-energy-efficiency-electric-vehicle-supply-equipment.php#documentation.

Models—i.e., a modular system shall meet the eligibility criteria in both its maximum and minimum non-redundant configurations. If the maximum and minimum configuration Representative Models meet the ENERGY STAR qualification criteria at their respective output power levels, all intermediate configuration models within a Modular UPS Product Family may be qualified for ENERGY STAR.

Discussion Questions

19) Would the testing approach outlined here be appropriate for modular EVSE products that can be configured to be larger or smaller depending on the application?

VII. Request for Feedback

EPA appreciates feedback on these and any other related issues **by Monday, June 25th.** Please send comments to evse@energystar.gov. Registration for the EVSE Program Framework Document Version 1.1 webinar on **Monday, June 4, 2018 from 12:00 PM – 2:30 PM**, is available here. For any questions, please contact James Kwon, EPA, at Kwon.James@epa.gov or (202) 564-8538, or Emmy Feldman, ICF, at Emmy.Feldman@icf.com or (202) 862-1145.